



Government of Canada
Canadian Forestry Service
Gouvernement du Canada
Service canadien des forêts

Growth of Inland and Coastal Provenances of Balsam Fir

J. Peter Hall

Information Report N-X-256
Newfoundland Forestry Centre



NEWFOUNDLAND FORESTRY CENTRE

The Newfoundland Forestry Centre (NeFC) is an establishment of the Canadian Forestry Service. The Centre conducts most of the forestry research in the Newfoundland Region and is one of six similar regional establishments in Canada.

The objective of NeFC is to provide the scientific, technological and economic information and services required for the improvement, protection, and efficient utilization of the forest resources of the province of Newfoundland and Labrador. Its work is directed towards satisfying the requirements of the Provincial Government, the forest industry, federal agencies having forestry related programs and other clients of the Canadian Forestry Service; many of its studies are undertaken jointly with client agencies. The Centre attempts to bring the results of research to potential users by publishing information reports, articles in scientific journals, and by demonstrations of research results. It seeks to keep the public informed of its work by means of special displays, seminars, and related activities.

The NeFC program has three principal components - Forest Resources and Environmental Research, Forest Protection Research, and Forestry Development.

GROWTH OF INLAND AND COASTAL PROVENANCES OF BALSAM FIR

by J. Peter Hall

**INFORMATION REPORT N-X-256
1986**

**CANADIAN FORESTRY SERVICE
NEWFOUNDLAND FORESTRY CENTRE**

©Minister of Supply and Services Canada 1986

ISSN NO. 0704-7657

CAT. NO. Fo46-15/256E

ISBN NO. 0-662-15529-7

Copies of this report are available at no charge from:

Newfoundland Forestry Centre
Canadian Forestry Service
P.O. Box 6028
St. John's, Newfoundland
Canada A1C 5X8

Telephone No. 709-772-4117

ABSTRACT

In 1961 a study was established to test the hypothesis that balsam fir from the Avalon Peninsula was inherently slow-growing. Two coastal sources and two inland sources were planted in a randomized complete block experiment. After 30 years from seed, one of the inland sources was growing better than the other three. The growth rate of the coastal sources was less than that of the inland ones. There are some indications that the cause of the slow-growth of fir from the Avalon Peninsula is partly of genetic origin.

RÉSUMÉ

Une étude a été entreprise en 1961 afin de vérifier l'hypothèse selon laquelle le sapin baumier de la presqu'île Avalon avait une croissance lente. Deux provenances côtières et deux de l'intérieur ont été plantés dans un plan en blocs aléatoires. Trente ans après la plantation à partir de la graine, une des provenances de l'intérieur poussait plus rapidement que les trois autres. Le taux de croissance des provenances côtières était inférieur à celui des provenances de l'intérieur. Certaines indications portent à croire que la cause de la croissance lente du sapin baumier de la presqu'île Avalon est en partie génétique.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	i
RÉSUMÉ	i
LIST OF TABLES	iii
LIST OF FIGURES	iv
LIST OF APPENDICES	v
INTRODUCTION.....	1
METHODS.....	2
Seed Sources	2
Plantation Site	3
Plantation Design and Establishment	3
Remeasurements	4
RESULTS AND DISCUSSION	4
CONCLUSIONS	9
REFERENCES	10
APPENDICES	13

LIST OF TABLES

	<u>Page</u>
1. Average total height and diameter (at 1.3 m) of four balsam fir provenances at various ages from seed	5
2. Relative height growth rate of each provenance planted at Cormack	6

LIST OF FIGURES

	<u>Page</u>
1. Height growth of four balsam fir provenances between ages 20 and 30	7

LIST OF APPENDICES

	<u>Page</u>
I. Tree, shrub, and herb species on Cormack plantation site, 1986	13
II. Analysis of variance for height, diameter and moss for four balsam fir provenances	14



GROWTH OF INLAND AND COASTAL PROVENANCES OF BALSAM FIR

by

J. Peter Hall

INTRODUCTION

An apparent peculiarity of balsam fir (Abies balsamea (L.) Mill.) is its failure to grow beyond 12-13 metres (Wilton 1956, Wilton and Lewis 1956). Growth and yield studies have demonstrated that the 'Avalon fir' was consistently shorter than comparably aged balsam fir elsewhere in Newfoundland (Page and van Nostrand 1970, 1973). Juvenile growth of balsam fir is as rapid as balsam fir elsewhere on the Island, but slows at an earlier age.

This low growth rate could be caused by the environmental conditions of the area, exposure to strong onshore winds, and short cool summers. These factors, however, do not affect the early height growth of fir. The trees could have evolved an ecotype characterized by high taper, heavy branching and poor height growth.

An experiment to explain this pattern of height growth was established by the Canadian Forestry Service in 1961. Sources of coastal and inland balsam fir were planted on both coastal and inland sites. If the pattern of height growth has an environmental explanation then trees growing on an inland site should grow equally well regardless of origin. If the cause is genetic then the rate of growth of the coastal sources would slow before the inland ones.

Results of the study have been reported previously, when the trees were nine years from seed (van der Pas 1966), 14 years (Richardson 1971) and 20 years (Khalil 1977). This report describes the results of a measurement at 30 years.

METHODS

Seed Sources

An inland and coastal source from both Newfoundland and New Brunswick were planted. The sources were:

- 232 - Newfoundland, 47°30'N lat., 52°55'W long., elev. 120-150 m,
Avalon Peninsula, Three Island Pond (coastal stand showing typical
Avalon fir height growth pattern).
- 123 - Newfoundland, 48°46'N lat., 56°00'W long., elev. 240 m,
Central Newfoundland, Sandy Brook, Badger (inland stand of good
growth).
- 190 - New Brunswick, 45°25'N lat., 65°25'W. long., elev. 120-180 m,
St. John Co. Salmon River/St. Martin's (coastal stand of good
growth).
- 186 - New Brunswick, 45°59'N lat., 66°23'W long., elev. 60 m., Acadia
Forest Experiment Station (AFES)(inland stand of good growth).

The seed was collected in 1955 and 1956, sown in the nursery at Acadia Forest Experiment Station and grown to 2 + 2. The seed from coastal Newfoundland consisted of A.b. var. phanerolepis Fern. (bracted balsam fir) and the other Newfoundland source was a mixture of bracted and non-bracted fir. The two New Brunswick sources were non-bracted.

While in the nursery the seedlings were sprayed twice with a nicotine solution to control Adelges aphids which were common in central New Brunswick at the time (MacGillivray 1959).

Plantation Site

Two plantations were established-one on the Avalon Peninsula (coastal site) the other near Cormack in western Newfoundland (inland site). The Avalon Peninsula site was destroyed by road construction and the trees were not measured beyond fourteen years from seed (Richardson 1971). Results are therefore based only on the inland site located in Forest Section B.28b at Cormack, 49°22'N lat., 53°19'W long. at 120 m elevation (Rowe 1972). The site formerly supported a stand of balsam fir and white birch (Betula papyrifera (Marsh.) which was burned by wildfire in 1949 and was unstocked at the time of planting. The plantation is on the lower south-facing slope of a low ridge. The soil is a rapidly-drained, deep, stone-free, red-brown clay loam showing little evidence of podzolization. There is some regeneration and a rich and varied herb and moss cover on the site (Appendix I).

Plantation Design and Establishment

Seed sources were planted in a randomized complete block replicated four times (Steel and Torrie 1960). Each plot contains 12 rows of 12 trees planted at a spacing of 1.8 m. The pit planting method was used and the stone-free soils allowed for rapid establishment. The plantation was established between 26 May and 2 June 1961. Weather during the period was cool (5°-12°C) and showery (Howard and Wilton 1962). Each plot was surrounded by one row of trees of provenance 123.

After two growing seasons dead trees (38) were replaced in the plantation, increasing survival to 100%. In 1964 and 1968 the plantation was weeded and trees or shrubs overtopping the planted trees were removed.

Remeasurements

Survival and height were measured in 1966 and 1970 and height and diameter in 1976 and 1986. Data were analysed by ANOVA techniques (Steel and Torrie 1960). For the 1986 remeasurements 36 trees were randomly selected in each of the plots.

RESULTS AND DISCUSSION

Survival has been very high in the plantation since its establishment. Only 38 of 2304 planted (1.6%) had died after two growing seasons. Severe summer frosts in 1964 killed 21% of seedlings in one of the plots which was located in a frost pocket (van der Pas 1966). The remainder of the plantation was unaffected and by 1970, 10 growing seasons after planting, three of the four provenances averaged 98% survival and the provenance with one frost damaged plot (186) averaged 93% (Richardson 1971). The plantation was severely defoliated by the spruce budworm, Choristoneura fumiferana Clem., between 1976 and 1978 but no noticeable mortality occurred and recovery was complete by 1982.

Height and diameter varied little among provenances during the first 20 years (Table 1). No data are available on seedling heights at time of planting so it is not known if all provenances were of equal

Table 1. Average total height and diameter (at 1.3 m) of four balsam fir provenances at various ages from seed.

Provenance origin	Habitat	Height (m)				Diameter (cm)	
		Age from seed				20	30
		9	14	20	30		
Newfoundland - Avalon Peninsula (232)	Coastal	.62a [‡]	1.89a	5.11a	6.52a	3.8a	9.3a
New Brunswick - St. Martin's (190)	Coastal	.62a	1.88a	4.98a	6.55a	3.7a	9.1a
Newfoundland - Sandy Brook (123)	Inland	.56a	1.66a	4.75a	6.42a	3.6a	8.9a
New Brunswick - Acadia FES (186)	Inland	.60a	1.90a	5.27a	7.51	3.9a	10.2

[‡]Means in column followed by the same letter are not significantly different from each other at $P = 0.95$.

height at age four, however five years after planting the largest difference between provenances was only 6 cm. Since age nine the central Newfoundland provenance has been the shortest. By age 14 provenance 186 was the tallest and this provenance is now significantly greater in height and diameter than the other three provenances (Table 1, Appendix II).

Provenance trials of balsam fir elsewhere have found large between provenance variation based on height (Lester *et al.* 1977, Lowe *et al.* 1977). These differences were considered large enough to influence choice of seed source even though the trees were only 8 and 11 years old. At that age there were no statistical differences in height in the Newfoundland data and absolute difference were very small. The provenance trials outside Newfoundland indicated that sources close to the

planting sites had superior growth (Lester et al. 1977, Lowe et al. 1977). However in the Newfoundland test the sources close to the planting site grew more slowly than a source from several hundred kilometres distant. Clearly the sources in the Newfoundland trial show different growth patterns from those reported elsewhere.

A comparison of height at various ages gives a measure of the relative growth rate uncomplicated by absolute tree heights (Evans 1972)¹. There is a consistent trend of lower ratios for the two coastal sources compared to the inland ones (Table 2). The source from Acadia consistently has the highest ratio and the coastal Newfoundland source has the lowest (Table 2, Figure 1). This suggests that the growth rate

Table 2. Relative height growth rate of each provenance planted at Cormack.

Provenance origin	Habitat	Relative Height Growth Rate for Three Periods		
		9-14	14-20	20-30
Newfoundland - Avalon Peninsula	Coastal	.254	.537	.141
New Brunswick - St. Martins	Coastal	.252	.467	.157
Newfoundland - Sandy Brook	Inland	.180	.515	.167
New Brunswick - Acadia	Inland	.260	.562	.224

¹Relative growth rate Newfoundland Coastal Source =

$$\frac{\text{Ht @ A} = 14 - \text{Ht @ A} = 9}{14 - 9}, \frac{1.89 - .62}{14 - 9} = .254$$

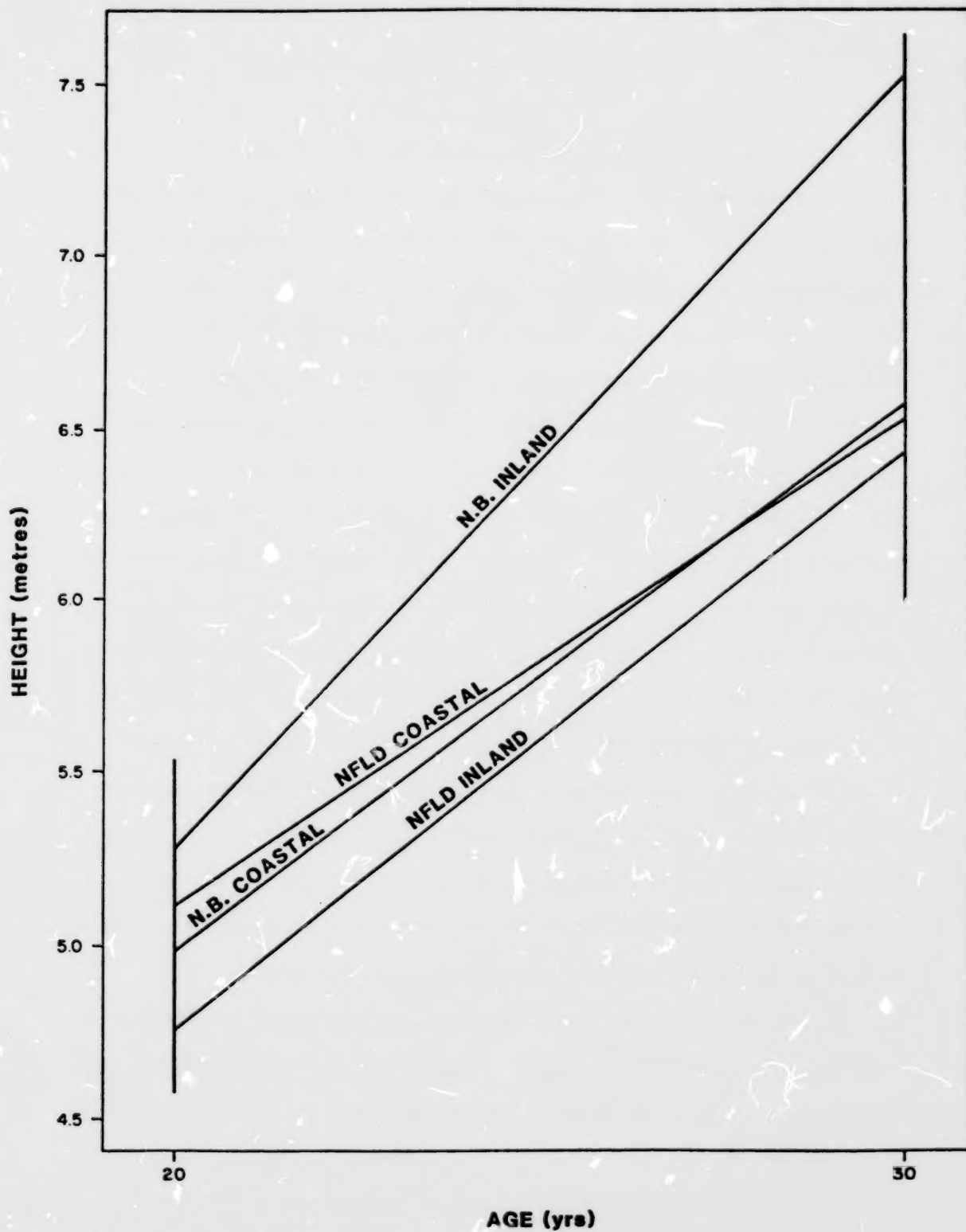


FIGURE 1. HEIGHT GROWTH OF FOUR BALSAM FIR PROVENANCES BETWEEN AGES 20 AND 30

of the coastal source is declining. Since the environmental constraint (coastal exposure, short cool summers) is largely removed, this supports the theory that the cause of the slow growth rate of coastal balsam fir is partly genetic.

Provenance trials elsewhere indicate superiority of New Brunswick and eastern Quebec provenances over central Canadian and U.S. sources (Lester et al. 1976, Lowe et al. 1977). There is also clinal variation in growth rate from south to north. Phylogenetic studies have also suggested that all Abies in eastern North America is a species complex with regional variations expressed as A. fraseri (Pursh.) Poir., A. balsamea and A.b. var. phanerolepis Fern. (Thor and Barnett 1973). Balsam fir therefore, is a variable and well adapted species occupying a wide variety of habitats. The phenotypic variation observed in Newfoundland led to the establishment of a study to test the genetic basis of these phenotypes. The most pronounced changes in growth rate were believed to occur at about 30 years, and results from this study indicate that a change is occurring with an increase of the growth rate of the Acadia source, a constant growth of the inland Newfoundland source and a decreasing growth rate of the two coastal sources.

It is reasonable to assume that in a widespread and diverse population there has been a degree of adaptation to distinct climatic conditions. It is suggested that adaptation based on local climate occurs in balsam fir (Lowe et al. 1977). These data support that view and suggest that the reduced growth rate of Avalon balsam fir has a strong hereditary component.

CONCLUSIONS

1. There are indications that the reduced growth rate of semi-mature balsam fir is under some genetic control.
2. The two coastal provenances have the slowest growth rates of the four sources and this trend developed between age 20 and 30.
3. One provenance of balsam fir from central New Brunswick is growing significantly better than all others.

REFERENCES

- Evans, G.C. 1972. The Quantitative Analysis of Plant Growth.
University of California Press, Berkeley and Los Angeles. 734 p.
- Howard, E.W. and W.C. Wilton. 1962. Provenance Plantations for
New Brunswick and Newfoundland Balsam Fir. Can. Dep. Forest., For.
Res. Br., St. John's, Nfld., Publ. 62-4, 6 p.
- Khalil, M.A.K. 1977. Twenty year results of the study of premature loss
of growth of balsam fir in southeastern Newfoundland. Env. Can.,
Forest. Ser., Nfld. For. Res. Can., St. John's, Nfld. Inform. Rep.
N-X-152. 9 p.
- Lester, D.T., C.A. Mohn and J.W. Wright. 1976. Geographic variation in
balsam fir: 11 year results in the Lake States. Can. J. For. Res.
6:389-394.
- Lester, D.T., S.E. Lindow and C.D. Upper. 1977. Freezing injury and
shoot elongation in balsam fir. Can. J. For. Res. 7:584-588.
- Lowe, W.J., H.W. Hocker, Jr. and M.L. McCormick, Jr. 1977. Variation in
balsam fir provenances planted in New England. Can. J. For. Res.
7:63-67.
- MacGillivray, H.G. 1959. A study of the premature loss of vigour of
balsam fir growing in some parts of Newfoundland, 1957, spring
sowing. Can. Dep. Nor. Aff. and Nat. Res., Forest. Br., Maritimes
Dist., Fredericton, N.B. Progress Report and Project Plan 1959.
14 p.

- Page, G. and R.S. van Nostrand. 1970. A study of the mensurational characteristics of some important forest types of eastern Newfoundland. Can. Dep. Fish. and Forest., Can. Forest. Ser., For. Res. Lab., St. John's, Nfld., Inform. Rep. N-X-47, 100 p.
- Page, G. and R.S. van Nostrand. 1973. Empirical yield tables for the major forest cover types of Newfoundland. Env. Can., Forest. Ser., Nfld. For. Res. Centre, St. John's, Nfld., Inform. Rep. N-X-100. 84 p.
- Richardson, J. 1971. Development of four balsam fir provenances in Newfoundland. Can. Dep. Fish. and Forest., Can. Forest. Ser., For. Res. Lab., St. John's, Nfld., Inform. Rep. N-X-60. 18 p.
- Rowe, J.S. 1972. Forest regions of Canada. Can. Dep. of the Env., Can. Forest. Ser. Publ. 1300, 172 p.
- Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co. New York, 481 p.
- Thor, E. and P.E. Barnett. 1974. Taxonomy of Abies in the southern Appalachians: variation in balsam monoterpenes and wood properties. For. Sci. 20:32-40.
- van der Pas, J.B. 1966. Provenance plantations for New Brunswick and Newfoundland balsam fir. Can. Dep. For., For. Res. Br., St. John's, Nfld. File Rep., Project NF-60, 5 p.

Wilton, W.C. 1956. Forest resources of the Avalon Peninsula, Newfoundland. Can. Dep. Nor. Aff. and Nat. Res., Forest. Br., For. Res. Div., Tech. Note No. 50, 33 p.

Wilton, W.C. and H.S. Lewis. 1956. Forestry problems of the Bonavista Peninsula, Newfoundland. Can. Dep. Nor. Aff. and Nat. Res., Forest. Br., For. Res. Div., Tech. Note No. 26, 31 p.

Appendix I. Tree, shrub, and herb species on Cormack plantation site, 1986.

Trees:

Black spruce	<u>Picea mariana</u> (Mill.) B.S.P
White spruce	<u>Picea glauca</u> (Moench) Voss
Trembling aspen	<u>Populus tremuloides</u> Michx.
White birch	<u>Betula papyrifera</u> Marsh.
Pin cherry	<u>Prunus pensylvanica</u> L.f.

Shrubs:

Willows	<u>Salix</u> spp.
Elderberry	<u>Sambucus pubens</u> Marsh.
Dogwood	<u>Cornus stolonifera</u> Michx.

Ground vegetation:

Clubmosses	<u>Lycopodium obscurum</u> L., <u>L. complanatum</u> , L., <u>L. annotinum</u> L., <u>L. clavatum</u> L.
Bunchberry	<u>Cornus canadensis</u> L.
Sarsparilla	<u>Aralia nudicaulis</u> L.
Pearly everlasting	<u>Anaphalis margaritacea</u> (L.) C.B. Clarke
Goldenrod	<u>Solidago canadensis</u> L.
Smilacina	<u>Smilacina trifolia</u> (L.) Desf.
Maianthemum	<u>Maianthemum canadense</u> Desf.
Clintonia	<u>Clintonia borealis</u> (Ait.) Raf.
Reindeermoss	<u>Cladonia</u> spp.
Hair cap moss	<u>Polytrichum commune</u> Hedw.
Woodfern	<u>Dryopteris spinulosa</u> (O.F. Muell) Watt.

Appendix II. Analysis of variance for height, diameter and mass for four balsam fir provenances.

ANOVA - Height based on plot means, age 9 (van der Pas 1966).

Source	df	SS	MS	F
Provenances	3	17.124	5.708	.324 n.s.
Replicates	3	85.994	31.998	1.814 n.s.
Error	9	158.763	17.640	
Total	15	261.881	-	

ANOVA - Height at ages 14 and 20 and diameter at age 20 based on individual trees (Khalil 1977).

Source	df	Height, 14 years			Height, 20 years			Diameter, 20 years		
		SS	MS	F	SS	MS	F	SS	MS	F
Provenances	3	66.77	22.26	1.17 n.s.	6.87	2.29	1.92 n.s.	20.41	6.80	1.82 n.s.
Replicates	3	91.99	30.66	1.62 n.s.	5.33	1.78	1.49 n.s.	17.46	5.82	1.56 n.s.
Prov. X Rep. Int.	9	170.51	18.95	6.36***	10.72	1.19	1.66 n.s.	33.68	3.74	1.50 n.s.
Error	560	1670.16	2.98		402.66	0.72		1395.54	2.49	
Total	575	1999.43			425.58			1467.09		

ANOVA - Height and diameter at age 30 based on individual trees.

Source	df	Height, 30 years			Diameter, 30 years		
		SS	MS	F	SS	MS	F
Provenances	3	113.25	37.75	5.45*	147.43	49.14	7.40**
Replicates	3	37.28	12.43	1.79 n.s.	52.50	17.50	2.64 n.s.
Prov. X Rep. Int.	9	62.36	6.93	6.93***	59.80	6.64	2.11*
Error	560	561.15	1.00		1763.86	3.15	
Total	575	744.05			2023.59		